

Polycyclic Aromatic Hydrocarbons and Benzo[a]pyrene (BaP):

Changes to MTCA Default Cleanup Levels for 2017 (April 2019 DRAFT)

Summary

In January, 2017, the U.S. Environmental Protection Agency (EPA) published several changes to the toxicity values for benzo[a]pyrene in its Integrated Risk Information System (IRIS) database. Also, EPA determined that benzo[a]pyrene has a mutagenic mode of action and therefore recommends the use of ADAFs (age-dependent adjustment factors) to address increased childhood sensitivity (compared to adults) to its carcinogenic (cancer-causing) effects.

These changes affect some Model Toxics Control Act Method B and Method C cleanup levels for BaP and for carcinogenic polycyclic aromatic hydrocarbons (cPAHs). This memorandum describes the updated toxicity values and how they affect default MTCA cleanup levels.

Table 1, below, lists updated default MTCA cleanup levels for cPAH mixtures and benzo[a]pyrene.

	Default Cleanup Level (1)	Regulatory Basis
Groundwater Method A	0.1 µg/L	MTCA Table 720-1
Groundwater Method B	0.2 µg/L	EPA Maximum Contaminant Level
Groundwater Method C	0.2 µg/L	EPA Maximum Contaminant Level
Surface Water Method B	1.6E-05 µg/L Fresh and Marine Water	EPA 40 CFR 131.45
Surface Water Method C	1.6E-05 µg/L Fresh and Marine Water	EPA 40 CFR 131.45
Soil Method A Unrestricted	0.1 mg/kg	MTCA Table 745-1
Soil Method A Industrial	2 mg/kg	MTCA Table 740-1
Soil Method B	0.19 mg/kg	MTCA Equation 740-2
Soil Method C	130 mg/kg	MTCA Equation 740-2 adjusted for Method C
Soil Protective of Groundwater (vadose)	3.9 mg/kg	MTCA Equation 747-1
Soil Protective of Groundwater (saturated)	0.19 mg/kg	MTCA Equation 747-1 adjusted for saturated zone
Air Method B (2)	1.1E-03 µg/m ³	MTCA Equation 750-2
Air Method C (2)	1.1E-02 µg/m ³	MTCA Equation 750-2 adjusted for Method C

(1) These are not necessarily final cleanup levels. These values may need to be adjusted for additive risk, PQLs, and natural background per WAC 173-340-720(7); -730(5); -740(5); -745(6); -750(5).

(2) For benzo[a]pyrene as an individual compound, the air cleanup levels based on noncancer effects are lower than the values in the table; $9.1\text{E-}04 \mu\text{g}/\text{m}^3$ for Method B and $2\text{E-}03 \mu\text{g}/\text{m}^3$ for Method C. There is currently no MTCA method for evaluating the noncancer effects of PAH mixtures.

I. EPA's Changes to Toxicity Values for Benzo[a]pyrene

For the carcinogenic effects of benzo[a]pyrene, EPA:

- Determined that benzo[a]pyrene has a mutagenic mode of action and recommended the use of age-dependent adjustment factors (ADAFs) to address the increased sensitivity of children (compared to adults) to its carcinogenic effects.
- Lowered the oral cancer slope factor from $7 (\text{mg}/\text{kg}\cdot\text{day})^{-1}$ to $1 (\text{mg}/\text{kg}\cdot\text{day})^{-1}$. The MTCA regulation refers to the "oral cancer slope factor" as the "oral cancer potency factor" but the toxicity numbers are the same.
- Added an inhalation unit risk (IUR) of $6 \times 10^{-4} (\mu\text{g}/\text{m}^3)^{-1}$. This IUR is equivalent to an inhalation cancer slope factor (CPF_i) of $2.1 (\text{mg}/\text{kg}\cdot\text{day})^{-1}$ which is used in MTCA Equation 750-2 to calculate a Method B cleanup level for carcinogenic effects. To convert the two parameters, the CPF_i includes body weight, breathing rate, and a factor to convert units: $\text{CPF}_i [\text{kg}\cdot\text{day}/\text{mg}] = \text{IUR} [\text{m}^3/\mu\text{g}] \times 70 \text{ kg} \div (20 \text{ m}^3/\text{day} \times 10^{-3} \text{ mg}/\mu\text{g})$.

These changes also affect MTCA cleanup levels for carcinogenic PAHs (cPAHs) because benzo[a]pyrene is the reference chemical used to calculate cPAH cleanup levels. MTCA methods to evaluate human health toxicity of cPAH mixtures using toxicity equivalency factors are described in the MTCA regulation (WAC 173-340-708(8)(e)) and in more detail [here](#).

Commented [j1]: This links to Toxics Cleanup Program Implementation Memorandum 10, "Evaluating the Human Health Toxicity of Carcinogenic PAHs (cPAHs) Using Toxicity Equivalency Factors (TEFs)".

For the noncancer effects of benzo[a]pyrene, EPA:

- Added an oral reference dose of $3 \times 10^{-4} \text{ mg}/\text{kg}\cdot\text{day}$.
- Added an inhalation reference concentration of $2 \times 10^{-6} \text{ mg}/\text{m}^3$. This RfC is equivalent to an inhalation reference dose (RfDi) of $5.7 \times 10^{-7} \text{ mg}/\text{kg}\cdot\text{day}$ which is used in MTCA Equation 750-1 to calculate a Method B cleanup level for noncancer effects. To convert the two parameters, the RfDi includes body weight and breathing rate: $\text{RfDi} (\text{mg}/\text{kg}\cdot\text{day}) = \text{RfCi} (\text{mg}/\text{m}^3) \times 20 \text{ m}^3/\text{day} \div 70 \text{ kg}$.

II. How the MTCA Default Cleanup Levels for cPAHs and Benzo[a]pyrene Were Determined

II.1 Framework for Cleanup Level Determination

Cleanup levels for MTCA sites are selected from among several possible options, including:

- applicable state and federal laws,
- MTCA risk-based cleanup level equations, table values, and adjustments,
- ecological risk assessment determinations,
- background concentrations,
- practical quantitation limits.

The specific hazardous substance, the existence of applicable laws, the environmental medium that is contaminated, and site-specific factors influence the selection of the appropriate cleanup level for a site. As shown in Table 1, depending on the environmental medium and choice of MTCA Method, the default cleanup levels for benzo[a]pyrene and cPAH mixtures will be based on applicable federal and state laws, numbers in tables in the MTCA regulation, or values calculated using the MTCA equations.

II.2 Adjustments for Early-Life Exposure to Mutagenic Hazardous Substances

As noted above, EPA has determined that benzo[a]pyrene has a mutagenic mode of action and recommends the use of Age-Dependent Adjustment Factors (ADAFs) to address the increased sensitivity of children (compared to adults) to its carcinogenic effects. This affects the calculation of Method B cleanup levels using the MTCA equations, resulting in lower cleanup levels compared to standard calculations. Previously, Ecology used this approach to calculate cleanup levels for trichloroethylene, a mutagenic hazardous substance. The adjustment methods are based on information in EPA document EPA/630/R-03/003F, "Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens" published in March 2005.

As recommended by EPA, the ability of a mutagen, such as benzo[a]pyrene, to cause cancer in children less than 2 years of age is assumed to be 10 times greater than in adults. In practice, the cancer potency factor is multiplied by a 10-fold Age-Dependent Adjustment Factor (ADAF) for cleanup level calculations that include exposure to children up to 2 years of age. Similarly, the ability of a mutagen to cause cancer in children from their second through sixteenth birthday is assumed to be 3 times greater than in adults, and the cancer potency factor is multiplied by an ADAF of 3 when children in that age range are exposed.

To calculate an Early Life Exposure adjustment (ELE), the ADAF is combined with certain exposure parameters that can change with age in the MTCA cleanup level equations (intake rate for soil, water, or air; body weight; exposure duration). This ELE is substituted into the MTCA equations for those exposure parameters to derive a cleanup level. The calculations start with the MTCA Equations for carcinogens for potable surface water and groundwater (720-2), surface water (730-2), soil (740-2), and air (750-2). Depending on the environmental medium (soil, groundwater, surface water, or air) age-specific adjustments are made to the equations, based on the parameters in Table 2.

Table 2. Age-Specific Adjustments for Early-Life Exposure

Parameter	Abbreviation	<2 years old	2 to <6 years old	6 to <16 years old	16 to 30 years old
Age-Dependent Adjustment Factor (unitless)	ADAF	10	3	3	1
Exposure Duration (years)	ED	2	4	10	14
Drinking Water Ingestion Rate (liters/day)	DWIR	1	1	2	2
Soil Ingestion Rate (milligrams/day)	SIR	200	200	50	50
Body Weight (kilograms)	BW	16	16	70	70
Breathing Rate (cubic meters/day)	BR	10	10	20	20

Detailed calculations for ELEs and cleanup levels for the various environmental media are described in the sections below.

II.2.a MTCA Soil calculations for benzo[a]pyrene and cPAHs

Step 1. Without the ELE adjustment, the MTCA Method B Equation 740-2 is normally used to calculate Soil Cleanup levels for carcinogens (from WAC 173-340-740):

$$\text{Soil Cleanup Level} \left(\frac{\text{mg}}{\text{kg}} \right) = \frac{\text{RISK} \times \text{ABW} \times \text{AT} \times \text{UCF}}{\text{CPFo} \times \text{SIR} \times \text{AB1} \times \text{ED} \times \text{EF}}$$

Table 2 – Default parameters for Equation 740-2.

Parameter	Abbreviation	Default Value	Units
Increased Cancer Risk	RISK	1 x 10 ⁻⁶	unitless
Average Body Weight	ABW	16	kilograms
Averaging Time	AT	75	years
Unit Conversion Factor	UCF	1 x 10 ⁶	milligrams/kilogram

Oral Cancer Potency Factor	CPFo	Chemical-specific*	kilograms-day/milligram
Soil Ingestion Rate	SIR	200	milligrams/day
Absorption Fraction	AB1	1	unitless
Exposure Duration	ED	6	years
Exposure Frequency	EF	1	unitless

*For benzo[a]pyrene, the CPFo = (1 kilogram-day)/milligram.

Step 2.

The soil cleanup level equation is based on exposures that occur during the first 6 years of life (birth through the 6th birthday). However, since the ADaF is reduced from 10 to 3 at the second birthday, two separate calculations are needed; one from birth to age 2, and another from age 2 to age 6. The exposure duration is also changed to be consistent with the ADaF age ranges. The ELE adjustment is calculated as follows:

$$\begin{aligned} \text{ELE (soil)} &= ((\text{ADaF}_{<2y} \times \text{ED}_{<2y} \times \text{SIR}_{<2y}) / \text{BW}_{<2y}) + ((\text{ADaF}_{2-6y} \times \text{ED}_{2-6y} \times \text{SIR}_{2-6y}) / \text{BW}_{2-6y}) = \\ &= ((10 \times 2 \text{ y} \times 200 \text{ mg/d}) / 16 \text{ kg}) + ((3 \times 4 \text{ y} \times 200 \text{ mg/d}) / 16 \text{ kg}) = \\ &= \mathbf{400 \text{ (milligram-year)/(kilogram-day)}} \end{aligned}$$

This is substituted into the soil cleanup level equation, replacing the equivalent parameters:

$$\begin{aligned} \text{Soil Cleanup Level } \left(\frac{\text{mg}}{\text{kg}} \right) &= \frac{\text{RISK} \times \text{AT} \times \text{UCF}}{\text{CPFo} \times \text{AB1} \times \text{EF} \times \text{ELE}} \\ &= \frac{0.000001 \times 75 \text{ y} \times 1,000,000 \text{ mg/kg}}{1 \times \frac{(kg - d)}{mg} \times 1 \times 1 \times 400 \text{ (mg} \cdot \text{y)} / (kg - d)} \\ &= \mathbf{0.1875 \text{ mg/kg (rounded to 0.19 mg/kg)}} \end{aligned}$$

II.2.b MTCA Groundwater calculations for benzo[a]pyrene and cPAHs

Step 1. Without the ELE adjustment, the MTCA Method B Equation 720-2 is normally used to calculate Groundwater Cleanup levels for carcinogens (from WAC 173-340-720):

$$\text{Groundwater Cleanup Level } \left(\frac{\mu\text{g}}{\text{L}} \right) = \frac{\text{RISK} \times \text{ABW} \times \text{AT} \times \text{UCF}}{\text{CPFo} \times \text{DWIR} \times \text{ED} \times \text{INH} \times \text{DWF}}$$

Parameter	Abbreviation	Default Value	Units
Increased Cancer Risk	RISK	1×10^{-6}	unitless
Average Body Weight	ABW	70	kilograms
Averaging Time	AT	75	years
Unit Conversion Factor	UCF	1×10^3	micrograms/milligram
Oral Cancer Potency Factor	CPFo	Chemical-specific*	kilograms-day/milligram
Drinking Water Ingestion Rate	DWIR	2	liters/day
Exposure Duration	ED	30	years
Inhalation Correction Factor	INH	1	unitless
Drinking Water Fraction	DWF	1	unitless

*For benzo[a]pyrene, the CPFo = (1 kilogram-day)/milligram.

Step 2.

The groundwater cleanup level equation is based on exposures that occur during the first 30 years of life (birth through the 30th birthday). The ADAF changes from 10 to 3 at the second birthday, and from 3 to 1 at age 16. Also, the body weight and drinking water ingestion rate change at age 6. The calculation of the ELE adjustment requires four separate calculations; one from birth to age 2, one from age 2 to age 6, one from age 6 to age 16, and one from age 16 through age 30. The ELE adjustment is calculated as follows:

$$\begin{aligned} \text{ELE (groundwater)} &= ((\text{ADAF}_{<2\text{y}} \times \text{ED}_{<2\text{y}} \times \text{DWIR}_{<2\text{y}}) / \text{BW}_{<2\text{y}}) + ((\text{ADAF}_{2-6\text{y}} \times \text{ED}_{2-6\text{y}} \times \text{DWIR}_{2-6\text{y}}) / \text{BW}_{2-6\text{y}}) + \\ &((\text{ADAF}_{6-16\text{y}} \times \text{ED}_{6-16\text{y}} \times \text{DWIR}_{6-16\text{y}}) / \text{BW}_{6-16\text{y}}) + ((\text{ADAF}_{16-30\text{y}} \times \text{ED}_{16-30\text{y}} \times \text{DWIR}_{16-30\text{y}}) / \text{BW}_{16-30\text{y}}) = \\ &((10 \times 2 \text{ y} \times 1 \text{ L/d}) / 16 \text{ kg}) + ((3 \times 4 \text{ y} \times 1 \text{ L/d}) / 16 \text{ kg}) + ((3 \times 10 \text{ y} \times 2 \text{ L/d}) / 70 \text{ kg}) + ((1 \times 14 \text{ y} \times 2 \text{ L/d}) / 70 \text{ kg}) = \\ &\mathbf{3.26 \text{ (liter-year)/(kilogram-day)}} \end{aligned}$$

This is substituted into the groundwater cleanup level equation, replacing the equivalent parameters:

$$\text{Groundwater Cleanup Level } \left(\frac{\mu g}{L} \right) = \frac{RISK \times AT \times UCF}{CPFo \times INH \times DWF \times ELE}$$

$$= \frac{0.000001 \times 75 \text{ y} \times 1,000 \mu g/mg}{1 \frac{(kg - d)}{mg} \times 1 \times 1 \times 3.26 (L - y)/(kg - d)}$$

$$= 0.023 \mu g/L$$

However, the EPA and Washington State Maximum Contaminant Levels (MCL) for drinking water are both 0.2 µg/L. Since this MCL is an applicable federal and state law and is associated with an increased cancer risk of less than one in one hundred thousand, it is considered sufficiently protective and is the appropriate default MTCA Method B groundwater cleanup level. See the MTCA regulation (WAC 173-340-720(7)(b)).

II.2.c MTCA Surface Water calculations for benzo[a]pyrene and cPAHs

Step 1. Without the ELE adjustment, the MTCA Method B Equation 730-2 is normally used to calculate Surface Water Cleanup levels for carcinogens (from WAC 173-340-730):

$$\text{Surface Water Cleanup Level } \left(\frac{\mu g}{L} \right) = \frac{RISK \times ABW \times AT \times UCF1 \times UCF2}{CPFo \times BCF \times FCR \times FDF \times ED}$$

Parameter	Abbreviation	Default Value	Units
Increased Cancer Risk	RISK	1 x 10 ⁻⁶	unitless
Average Body Weight	ABW	70	kilograms
Averaging Time	AT	75	years
Unit Conversion Factor 1	UCF1	1 x 10 ³	micrograms/milligram

Unit Conversion Factor 2	UCF2	1 x 10 ³	grams/liter
Oral Cancer Potency Factor	CPFo	Chemical-specific*	kilograms-day/milligram
Bioconcentration Factor	BCF	30*	liters/kilogram
Fish Consumption Rate	FCR	54	grams/day
Fish Diet Fraction	FDF	0.5	unitless
Exposure Duration	ED	30	years

*For benzo[a]pyrene, the CPFo = (1 kilogram-day)/milligram.

Step 2.

The surface water cleanup level equation is based on exposures that occur during the first 30 years of life (birth through the 30th birthday). The ADAF changes from 10 to 3 at the second birthday, and from 3 to 1 at age 16. Also, the body weight changes at age 6. This requires four separate calculations; one from birth to age 2, one from age 2 to age 6, one from age 6 to age 16, and one from age 16 through age 30.

$$\begin{aligned}
 \text{ELE (surface water)} &= ((\text{ADAF}_{<2y} \times \text{ED}_{<2y} \times \text{FCR}_{<2y}) / \text{BW}_{<2y}) + ((\text{ADAF}_{2-6y} \times \text{ED}_{2-6y} \times \text{FCR}_{2-6y}) / \text{BW}_{2-6y}) + \\
 &((\text{ADAF}_{6-16y} \times \text{ED}_{6-16y} \times \text{FCR}_{6-16y}) / \text{BW}_{6-16y}) + ((\text{ADAF}_{16-30y} \times \text{ED}_{16-30y} \times \text{FCR}_{16-30y}) / \text{BW}_{16-30y}) = \\
 &((10 \times 2 \text{ y} \times 54 \text{ g/d}) / 16 \text{ kg}) + ((3 \times 4 \text{ y} \times 54 \text{ g/d}) / 16 \text{ kg}) + ((3 \times 10 \text{ y} \times 54 \text{ g/d}) / 70 \text{ kg}) + ((1 \times 14 \text{ y} \times 54 \text{ g/d}) / 70 \\
 &\text{ kg}) = \\
 &\mathbf{141.9 \text{ (gram-year)/(kilogram-day)}}
 \end{aligned}$$

This is substituted into the surface water cleanup level equation, replacing the equivalent parameters:

$$\text{Surface Water Cleanup Level} \left(\frac{\mu\text{g}}{\text{L}} \right) = \frac{\text{RISK} \times \text{AT} \times \text{UCF1} \times \text{UCF2}}{\text{CPFo} \times \text{BCF} \times \text{FDF} \times \text{ELE}}$$

$$= \frac{0.000001 \times 75 \text{ y} \times 1,000 \frac{\mu\text{g}}{\text{mg}} \times 1,000 \text{ g/L}}{1 \frac{(\text{kg} - d)}{\text{mg}} \times 30 \frac{\text{L}}{\text{kg}} \times 0.5 \times 141.9 \text{ (g} - \text{y}) / (\text{kg} - d)}$$

$$= 0.035 \mu\text{g/L}$$

Note that the MTCA regulation does not include a default child-specific fish consumption rate, so the adult rate is used for all ages for this calculation. A child-specific rate would likely be lower than the adult rate, resulting in a calculated cleanup level higher than 0.035 $\mu\text{g/L}$. However, as noted below, the appropriate Method B cleanup level is based on an applicable federal law, and is orders of magnitude lower than the value calculated with the MTCA Equation.

The EPA Quality criterion listed in 40 C.F.R. 131.45¹ is 0.000016 $\mu\text{g/L}$ for both fresh water and marine water. Since this is an applicable federal law and is lower than the level calculated above, the appropriate Method B cleanup level for both fresh water and marine water is 0.000016 $\mu\text{g/L}$.

II.2.d MTCA Air calculations for benzo[a]pyrene and cPAHs

Step 1. Without the ELE adjustment, the MTCA Method B Equation 750-2 is normally used to calculate Air Cleanup levels for carcinogens (from WAC 173-340-750):

$$\text{Air Cleanup Level } \left(\frac{\mu\text{g}}{\text{m}^3} \right) = \frac{\text{RISK} \times \text{ABW} \times \text{AT} \times \text{UCF}}{\text{CPF}_i \times \text{BR} \times \text{ABS} \times \text{ED} \times \text{EF}}$$

Parameter	Abbreviation	Default Value	Units
Increased Cancer Risk	RISK	1×10^{-6}	unitless
Average Body Weight	ABW	70	kilograms
Averaging Time	AT	75	years
Unit Conversion Factor	UCF	1×10^3	micrograms/milligram
Inhalation Cancer Potency Factor	CPF _i	Chemical-specific*	kilograms-day/milligram
Breathing Rate	BR	20	cubic meters/day
Inhalation Absorption Fraction	ABS	1	unitless
Exposure Duration	ED	30	years
Exposure Frequency	EF	1	unitless

¹ The National Toxics Rule (NTR; 40 C.F.R. 131.36) no longer applies to Washington State. EPA's federally promulgated water quality standards for Washington State are contained in 40 C.F.R. 131.45 – EPA's revision of certain federal water quality criteria applicable to Washington. These are human health criteria only.

*For benzo[a]pyrene, the CPFi = (2.1 kilogram-day)/milligram.

$$\begin{aligned} \text{ELE (air)} &= ((\text{ADAF}_{<2y} \times \text{ED}_{<2y} \times \text{BR}_{<2y}) / \text{BW}_{<2y}) + ((\text{ADAF}_{2-6y} \times \text{ED}_{2-6y} \times \text{BR}_{2-6y}) / \text{BW}_{2-6y}) + \\ &((\text{ADAF}_{6-16y} \times \text{ED}_{6-16y} \times \text{BR}_{6-16y}) / \text{BW}_{6-16y}) + ((\text{ADAF}_{16-30y} \times \text{ED}_{16-30y} \times \text{BR}_{16-30y}) / \text{BW}_{16-30y}) = \\ &((10 \times 2 \text{ y} \times 10 \text{ m}^3/\text{d}) / 16 \text{ kg}) + ((3 \times 4 \text{ y} \times 10 \text{ m}^3/\text{d}) / 16 \text{ kg}) + ((3 \times 10 \text{ y} \times 20 \text{ m}^3/\text{d}) / 70 \text{ kg}) + ((1 \times 14 \text{ y} \times 20 \\ &\text{m}^3/\text{d}) / 70 \text{ kg}) = \end{aligned}$$

$$32.6 \text{ (cubic meters-year)} / (\text{kilogram-day})$$

$$\text{Air Cleanup Level } \left(\frac{\mu\text{g}}{\text{m}^3} \right) = \frac{\text{RISK} \times \text{AT} \times \text{UCF}}{\text{CPFi} \times \text{ABS} \times \text{EF} \times \text{ELE}}$$

$$\begin{aligned} \text{Air Cleanup Level } \left(\frac{\mu\text{g}}{\text{m}^3} \right) &= \frac{0.000001 \times 75 \text{ y} \times 1000 \mu\text{g}/\text{mg}}{2.1 \frac{(\text{kg} - \text{d})}{\text{mg}} \times 1 \times 1 \times 32.6 \text{ (cubic meters - y)} / (\text{kg} - \text{d})} \\ &= 0.0011 \mu\text{g}/\text{m}^3 \end{aligned}$$